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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

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Inventor(s) or Application Identifier
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Title: SCANNING OPTICAL SYSTEM FOR TANDEM TYPE PRINTER

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, DC 20231

JC685 U.S. PTO 08/31/00

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APPLICATION ELEMENTS

1. ☒ Fee Transmittal Form
2. ☒ Specification [Total Pages 30]
   (preferred arrangement set forth below)
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. ☒ Drawing(s) (35 USC 113) [Total Sheets 7]
4. ☒ Oath or Declaration [Total Pages 3]
   a. ☐ Newly executed (original or copy) ☒ Unexecuted
   b. ☐ Copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   [Note Box 5 below]
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference (useable if Box 4b is checked)
   The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
   (if applicable, all necessary)
   a. ☐ Computer Readable Copy
   b. ☐ Paper Copy
   c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ☐ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☐ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)
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14. ☐ Small Entity Statement(s) ☐ Statement filed in prior application, Status still proper and desired
15. ☐ The prior application is assigned of record to ______________.
16. ☒ Foreign priority claimed
    a. ☒ Claim of Priority
    b. ☒ Certified Copy of Priority Document(s)
17. ☒ Other: Cover Letter under 37 C.F.R. 1.53(b) and (f)

18. **If a CONTINUING APPLICATION,** check appropriate box and supply the requisite information:
    ☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior Application No. ______/__________, filed __________.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Applicant : J. KAMIKUBO et al.

Serial No : Not Yet Assigned

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For : SCANNING OPTICAL SYSTEM FOR TANDEM TYPE PRINTER

COVER LETTER ACCOMPANYING U.S. PATENT APPLICATION
FILED UNDER 37 C.F.R. 1.53(b)and 1.53(f)

Commissioner of Patents and Trademarks
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Sir:

Enclosed is a new patent application for filing in the U.S. Patent and Trademark Office under 37 C.F.R. 1.53(b)and 1.53(f) in which the Declaration and Power of Attorney attached thereto are in unexecuted form. An executed Declaration and Power of Attorney will be filed within the time period set forth in the Notice to File Missing Parts of Application, unless such time period has been extended by the filing of a petition accompanied by the extension fee under the provisions of 37 C.F.R. 1.136(a).

Related to this, a correspondence address is provided in the unexecuted Declaration and Power of Attorney, and is as follows:

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The above-identified application includes:

- 30 pages of specification (including Abstract);
- 4 total claims; with 2 independent;
- 7 sheets of drawings with 7 figures;
- an unexecuted Declaration and Power of Attorney.

If there are any questions, please contact the undersigned at the below-listed telephone number.

Respectfully submitted,
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August 31, 2000
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Specification

Title of the Invention

Scanning Optical System for Tandem Type Printer

Background of the Invention

The present invention relates to a scanning optical system employed, for example, in a tandem type color laser beam printer.

Conventionally, a scanning optical system, which is employed, for example, in a tandem type color laser beam printer is known. Such a color laser beam printer includes a plurality of scanning optical systems and photoconductive drums corresponding to a plurality of color components of a color image formed by the color laser beam printer. In each scanning optical system, a laser diode, a polygonal mirror and an fθ lens are provided. The laser beam emitted by the laser diode is deflected by the polygonal mirror. The deflected laser beam is converged by the fθ lens and forms a beam spot on a surface to be scanned. Since the polygonal mirror is rotated, the deflected beam scans within a predetermined angular range. Thus, the beam spot formed on the surface to be scanned moves along a predetermined

scanning line, extending direction of which will be referred to as a main scanning direction. The surface to be scanned is a circumferential surface of a photoconductive drum. By using the plurality of scanning optical systems and the corresponding photoconductive drums for a plurality of color components, respectively, a plurality of color image components are printed, in an overlaid fashion, on the same sheet so that a color image is formed.

In such a tandem type color printer, i.e., a printer employing a plurality of scanning optical systems and photoconductive drums, in order to avoid color drift of an image, writing start position and writing end position of each scanning line of each color component should be adjusted accurately.

However, if the fθ lens of each scanning optical system has lateral chromatic aberration, and wavelength of a laser beam emitted by each laser diode has individual errors, then the writing start and/or end positions of the scan line may be different among the color components. In such a case, the color drift appear on a printed image and the quality of the formed image is deteriorated.

Summary of the Invention

It is therefore an object of the present invention to

provide an improved tandem type scanning optical system which is capable of preventing the color drift due to variation of wavelengths among the laser beams emitted by a plurality of light sources, and due to uneven distribution of refractive index caused by uneven temperature distribution inside the printer.

For the above object, according to the present invention, there is provided a tandem type printer that includes a plurality of scanning optical systems respectively having plurality of fθ lenses, and photoconductive drums, which correspond to the scanning optical systems, respectively. Each scanning optical system includes a laser source and a deflector that deflects the laser beam emitted by the laser source to scan, in a main scanning direction, within a predetermined angular range. The deflected laser beam is converged by the fθ lens on the corresponding photoconductive drum and form an image. Images formed on the plurality of photoconductive drums are developed and transferred on a sheet in an overlaid fashion. Each fθ lens includes a glass lens that is burdened with substantially all the power, in the main scanning direction, of the fθ lens, and a plastic lens that is burdened with compensation for aberrations of the fθ lens. Further, a diffraction lens structure is formed to compensate for a lateral chromatic aberration of the fθ lens in the main

scanning direction. Each fθ lens satisfies conditions:

$0.0 < fa/fd < 0.20$; and

$0.75 < fa/fg < 1.20$,

where, fa, fd and fg represent focal lengths of the fθ lens, diffraction lens structure, and glass lens, in the main scanning direction, respectively.

With this configuration, the lateral chromatic aberration is compensated by the diffraction lens structure. Further, since the glass lens is mainly burdened with the power in the main scanning direction, and change of refractive index due to variation of temperature affects little. Therefore, with a printer employing the scanning optical system according to the present invention, color drift of printed images due to variation of wavelengths of the laser beams for respective color components, and due to uneven distribution of temperature inside the printer can be suppressed, and color images can be printed accurately.

Optionally, the diffraction lens structure may be formed on a refraction surface of said plastic lens in each fθ lens.

Brief Description of the Accompanying Drawings

Fig. 1 is a side view of a tandem type printer illustrating an arrangement of optical elements therein;

Fig. 2 is a plan view of the scanning optical system according to a first embodiment;

Fig. 3 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 2;

Fig. 4 is a plan view of the scanning optical system according to a second embodiment;

Fig. 5 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 4;

Fig. 6 is a plan view of the scanning optical system according to a third embodiment; and

Fig. 7 is a graph showing lateral chromatic aberration of the scanning optical system shown in Fig. 6.

Detailed Description of the embodiments

Hereinafter, the embodiments according to the invention will be described in detail with reference to the accompanying drawings.

Fig. 1 is a side view of a printer to which embodiments according to the present invention can be applied. The printer shown in Fig. 1 is configured such that a color image is formed by printing black, cyan, yellow and magenta images on a sheet in an overlaid fashion. For this purpose, the printer includes a plurality of

scanning optical systems and photoconductive drums for the black, cyan, yellow and magenta components, respectively.

The printer shown in Fig. 1 has a housing 10 and a drum support 20. The housing 10 accommodates first through fourth scanning optical systems 100, 200, 300 and 400. The drum support 20 rotationally supports first through fourth photoconductive drums 21, 22, 23 and 24, which are exposed to scanning beams emitted from the first through fourth scanning optical system 100-400, respectively. The first through fourth photoconductive drums 21-24 are arranged such that rotation axes thereof are parallel to each other. Units (e.g., a developing unit, a transfer unit, a cleaning unit) for performing an electronic image forming process are provided around each of the photoconductive drums 21-24. Since such units are well-known, they are not shown in the drawing and description thereof is omitted for the sake of simplicity.

In the printer, a recording sheet is fed from a left-hand side to a right-hand side of Fig. 1 along a sheet feed path R. Then, toner images of respective color components (i.e., black, cyan, yellow and magenta components) are transferred from the first to fourth photoconductive drums 21-24 sequentially, thereby a color image being finally formed on the recording sheet. The color image thus transferred on the recording sheet is fixed thereon by a

fixing unit. The fixing process is also well-known in the field of electrophotographic process, and therefore, it is not shown in Fig. 1 and a detailed description will not be given.

Next, a configuration of the first scanning optical system 100 will be described in detail with reference to Figs. 1 and Fig. 2, which is a plan view showing an arrangement of optical elements of the first scanning optical system 100. It should be noted that all the scanning optical systems 100-400 are structurally the same, and therefore what is described in connection with the first scanning optical system 100 also applies to the other scanning optical systems 200-400.

As shown in Figs. 1 and 2, the first scanning optical system 100 is provided with:

a laser source unit 110 for emitting a collimated laser beam;

a polygonal mirror 120 for deflecting the collimated laser beam to scan, in a main scanning direction, within a predetermined angular range; and

an fθ lens 130 for converging the scanning laser beam on the circumferential surface of the photoconductive drum 21 to form a scanning line thereon. Strictly speaking, the laser beam passed through the fθ lens 130 is reflected by a mirror 140 (see Fig. 1), and then converged on the surface

of the photoconductive drum 21. However, since the mirror 140 functions only to bend an optical path, Fig. 2 is drawn as a developed view, omitting the mirror 140 therefrom. In Fig. 1, a rectangular coordinate system indicated by upper cases XYZ is shown. In Fig. 2, another rectangular coordinate system indicated by lower cases xyz is shown. In Fig. 1, the main scanning direction is defined as Y-axis direction, and an auxiliary scanning direction, which is perpendicular to the main scanning direction on the surface of the photoconductive drum 21, is defined as X-axis direction. In Fig. 2, the main scanning direction is defined as the y-axis direction, and the auxiliary scanning direction is defined as the z-axis direction.

As shown in Fig. 2, the laser source unit 110 includes a laser diode 111, and a collimating lens 112 for collimating the laser beam emitted by the laser diode 111. A cylindrical lens 115, which has positive power in the auxiliary scanning direction, is provided between the laser source unit 110 and the polygonal mirror 120. It should be noted that, in Fig. 1, the auxiliary direction at the photoconductive drum 21 is the X-axis direction. However, the auxiliary direction at the cylindrical lens 115 is the Z-axis direction since the laser beam is reflected by the mirror 140. In Fig. 2, since the mirror 140 is omitted from the drawing, the auxiliary direction is referred to as the

z-axis direction both at the photoconductive drum 21 and at the cylindrical lens 115.

The fθ lens 130 includes a first lens 131 and a second lens 132. Further, on a photoconductive drum side surface of the first lens, a Fresnel lens like diffraction lens structure 131a is formed. The first lens 131 is a plastic lens and burdened with (functions to) compensation for aberrations (e.g., curvature of field in the main scanning direction and errors of fθ characteristics). The second lens 132 is a glass lens and provides almost all the power, in the main scanning direction, of the fθ lens 130. The diffraction lens structure 131a is formed as a part of a pattern rotationally symmetrical about an optical axis of the fθ lens 130 and has a plurality of annular zones. The diffraction lens structure 131a functions to compensate for lateral chromatic aberration, in the main scanning direction, of the refractive lens structure of the fθ lens 130.

The laser beam deflected by the polygonal mirror 120, and passed through the first and second lenses 131 and 132 of the fθ lens 130 is, as shown in Fig. 1, reflected by a mirror 140 downward and incident on the first photoconductive drum 21. The polygonal mirror 120 rotates clockwise, in Fig. 2, and the deflected beam scans on the circumferential surface of the photoconductive drum in the

main scanning direction, i.e., in the y-axis direction in Fig. 2.

The collimated laser beam emitted by the laser source 110 is converged, only in the auxiliary scanning direction, on a plane closely adjacent to the reflection surface of the polygonal mirror 120. Then, the beam is deflected by the polygonal mirror 120, and is converged, by the fθ lens 130, on the photoconductive drum 21. With this configuration, facet error of the reflection surfaces of the polygonal mirror 120 can be compensated, and therefore, shift of the scanning line, in the auxiliary scanning direction, on the photoconductive drum 21 due to the facet error can be prevented.

As aforementioned, the second through fourth scanning optical systems 200-400 are configured similarly to the first scanning optical system 100. That is, the second scanning system 200 includes a laser source (not shown), a polygonal mirror 220 and an fθ lens 230 including first and second lenses, and a mirror 240. The second scanning system 200 forms a scanning line on the circumferential surface of the second photoconductive drum 22. The third scanning system 300 includes a laser source (not shown), a polygonal mirror 320 and an fθ lens 330 including first and second lenses, and a mirror 340. The third scanning system 300 forms a scanning line on the circumferential surface of the

third photoconductive drum 23. The fourth scanning system 400 includes a laser source (not shown), a polygonal mirror 420 and an fθ lens 430 including first and second lenses, and a mirror 440. The fourth scanning system 400 forms a scanning line on the circumferential surface of the third photoconductive drum 24.

Next, the structure of the fθ lens 130 will be described, and then numerical examples of the fθ lens 130 will be explained as three embodiments.

As aforementioned, the fθ lens 130 includes the first and second refractive lenses 131 and 132, and the diffraction lens structure 131a.

It is well-known that the diffraction lens structure has a dispersion, an absolute value of which is relatively large and sign of which is negative. Therefore, by combining the diffractive lens structure, having relatively small power, with the refractive lens, the lateral chromatic aberration can be compensated.

In order to reduce the lateral chromatic aberration and variation of the power due to a change of refractive index caused by a change in temperature, according to the embodiment, a glass lens is included in the fθ lens 130. The glass lens provides almost all the power in the main scanning direction.

Specifically, as aforementioned, the fθ lens 130 is

constructed to have the plastic lens (first lens) 131 which has almost no power in the main scanning direction and the glass lens (the second lens) 132 which provides almost all the power, in the main scanning direction, of the fθ lens 130. Since the glass lens 132 provides almost all the power of the fθ lens 130 in the main scanning direction, a change of power, due to a change of temperature, of the glass lens is very small, variation of power of the fθ lens 130 is well prevented. Further, by the diffraction lens structure 131a, in association with the refractive lenses 131 and 132, the lateral chromatic aberration can be compensated.

More specifically, the second lens 132 and the diffractive lens structure 131a are designed to satisfy conditions (1) and (2) below:

$$0.0 < fa/fd < 0.20 \quad \cdots (1)$$

$$0.75 < fa/fg < 1.20 \quad \cdots (2)$$

where, fa represents a focal length, in the main scanning direction, of the fθ lens 130;

fd represents a focal length, in the main scanning direction, of the diffraction lens structure 131a; and

fg represents a focal length, in the main scanning direction, of the second (glass) lens 132.

Conditions (1) and (2) define, in other words, the upper and lower limits of the power of the glass lens 132

and the diffraction lens structure 131a normalized by the power of the fθ lens 130.

In condition (1), if fa/fd is negative (i.e., smaller than 0.0), the lateral chromatic aberration of the diffractive lens structure 131a and that of the refractive lens structure are directed in the same direction, and therefore, the lateral chromatic aberration cannot be compensated by combining the diffractive lens structure 131a with the refractive lens sturucture. If fa/fd is greater than 0.20, the power of the diffraction lens structure 131a is too large, and the lateral chromatic aberration is overcorrected.

In condition (2), if fa/fg is smaller than 0.75, the power of the glass lens 132 is too small, and a positive power burdened by the plastic lens 131 is too large. If fa/fg exceeds 1.20, the power of the glass lens 132 is too large, and the amount of negative power provided by the plastic lens 131 is too large. In either case, the absolute value of the power provided by the plastic lens 131 is too large, which results in a relatively large change due to a change in temperature. Thus, if condition (2) is not satisfied, it is impossible to reduce both the lateral chromatic aberration and the change in power of the fθ lens 130 due to the change of the temperature.

It should be noted that, in general, a diffraction

lens structure can be expressed by a sag amount SAG(h) representing a distance between a plane, which is tangent to the diffraction lens structure at a point where the optical axis intersects with the diffraction lens structure, and a point on the diffraction lens structure at height (a distance from the optical axis) h. The sag amount SAG(h) is obtained by the following formula (3).

$$SAG(h) = X(h) + S(h) \quad \cdots\cdots (3)$$

where, X(h) represents a base curve of the surface on which the diffraction lens structure is formed. The base curve X(h) is expressed by the following formula (4).

$$X(h) = \left\{\frac{ch^2}{1+\sqrt{1-(\kappa+1)\cdot c^2h^2}}\right\} + A4h^4 + A6h^6 + A8h^8 + A10h^{10} \quad \cdots (4)$$

where, c=1/r, r represents radius of curvature on the optical axis, κ represents a conical coefficient, A4, A6, A8 and A10 represent fourth, sixth, eighth, and tenth aspherical coefficients.

An additional optical path length Δϕ(h) to be added by the diffraction lens structure is obtained by the following formula (5).

$$\Delta\phi(h) = P2h^2 + P4h^4 + P6h^6 + P8h^8 + P10h^{10} \quad \cdots (5)$$

where, Pn represents an n-th (n being an even number) order coefficient of an optical path difference function. The term S(h) in formula (3) is calculated in accordance with the following formula (6).

$$S(h) = \frac{\{MOD(\Delta\phi(h) + C, -1) - C\} \cdot \lambda}{n - 1 + Dh^2} \quad \cdots (6)$$

where, C is a constant for setting a phase of boundaries of the annular zones, and can be any desired value between 0 and 1 (C=0.5 in the following examples), and

D represents a coefficient to compensate for variation of additional phase which is caused as the light beam impinges on the diffraction lens structure obliquely,

λ represents a wavelength of the light beam.

As is known, MOD is a modulo function and MOD(a,b) is defined as:

$$MOD(a,b) = a - b \cdot INT(a/b).$$

A zone number corresponding to each zone is expressed by the formula (7).

$$N = INT(|\Delta\phi(h) + C|) \quad \cdots (7)$$

where, N=0 corresponds to a zone intersecting with the optical axis.

FIRST EMBODIMENT

Fig. 2 is a plan view of the scanning optical system 1000, showing an arrangement of optical elements, according to a first embodiment of the invention. In TABLE I, numerical structure of the optical elements, on the photoconductive drum side thereof with respect to the

cylindrical lens is indicated. In TABLE I, fa denotes a focal length of the fθ lens 130 in the main scanning direction, ry denotes a radius of curvature in the main scanning direction (i.e., y-axis direction in Fig. 2), rz denotes a radius of curvature (which is omitted for a rotationally symmetrical surface) in the auxiliary scanning direction (i.e., z-axis direction in Fig. 2), d denotes a distance between adjacent surfaces on the optical axis, and n denotes a refractive index at wavelength of 780 nm.

In TABLE I, surface #1 and #2 are the surfaces of the cylindrical lens 115, surface #3 is a mirror surface of the polygonal mirror 120, surfaces #4 and #5 are the surfaces of the first lens 131, and surfaces #6 and #7 are those of the second lens 132.

TABLE I

fa=199.9 mm   scan width:320 mm   design λ: 780 nm

No.	ry	rz	d	n
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
#3	inf.	--	67.00	
#4	-378.99	-30.95	8.00	1.48617
#5	-491.66	--	5.00	

#6	inf.	18.00		1.76591
#7	-154.30	-30.13	201.25	

Surface #4 is an aspherical surface, which does not have an axis of symmetry. A radius of curvature of a cross section of surface #4 taken along a plane parallel to an x-z plane spaced from the optical axis is set independently from the cross section taken along an x-y plane. Hereinafter, such a surface will be referred to as a progressive toric aspherical surface, which is expressed by the following formula (8).

$$x(y) = \frac{cy^2}{1+\sqrt{1-(\kappa+1)c^2y^2}} + A4y^4 + A6y^6 + A8y^8 + A10y^{10} \quad \cdots \ (8)$$

where, $c = 1/r$, and $\dfrac{1}{Rz} = \dfrac{1}{Rzo} + B1y + B2y^2 + B3y^3 + B4y^4$.

In the above equations, y represent an image height in the y-axis (i.e., the main scanning) direction, r denotes a radius of curvature, in the main scanning direction, on the optical axis. Curvature in the z-axis direction, at the height y in the main scanning direction, is represented by 1/Rz, and Rzo represents a radius of curvature, in the auxiliary scanning direction, on the optical axis (i.e., y=0). B1, B2, B3 and B4 represent coefficients representing change of the radius of curvature

in the auxiliary scanning direction.

Surface #5 is a surface on which the diffraction lens structure is formed, surface #6 is a planar (flat) surface, and surface #7 is a toric surface having an axis, which extends in the auxiliary scanning direction, of symmetry. That is, surface #7 is rotationally symmetrical about the axis. Such a toric surface will be referred to as a Z toric surface hereinafter. Conical coefficients and aspherical coefficients are indicated in TABLE II, while, a numerical structure of surface #5 (i.e., the diffraction lens structure) is indicated in TABLE III.

TABLE II

Aspherical coefficients for surface #4

κ	0.0		
A4	-1.782×10^{-6}	B1	-4.081×10^{-5}
A6	8.076×10^{-10}	B2	-1.757×10^{-5}
A8	-1.134×10^{-13}	B3	0.0
A10	0.0	B4	3.005×10^{-9}

TABLE III

fd at design wavelength: 3443.6 mm

Macroscopic shape

r	-491.66
κ	0.0
A4	-1.282×10^{-6}
A6	5.012×10^{-10}
A8	-5.585×10^{-14}
A10	0.0

Coefficients for additional path length $\Delta\phi(h)$

P2	-1.8615×10^{-1}
P4	-1.0817×10^{-5}
P6	1.5024×10^{-9}
P8	-3.1306×10^{-12}
P10	4.0862×10^{-16}
D	1.34×10^{-5}

Fig. 3 is a graph showing the lateral chromatic aberration of the scanning optical system according to the first embodiment.

SECOND EMBODIMENT

Fig. 4 is a plan view of the scanning optical system 2000, showing an arrangement of optical elements, according

to a second embodiment of the invention. The scanning optical system 2000 include an fθ lens 130a, which includes a first lens 133, a second lens 134, and a diffraction lens structure 133a formed on a surface of the first lens 133. The first lens 133 is a plastic lens, and the second lens 134 is a glass lens. In TABLE IV, a numerical structure of the optical elements, on the photoconductive drum side thereof with respect to the cylindrical lens is indicated. In TABLE IV, fa denotes a focal length of the fθ lens 130a in the main scanning direction, ry denotes a radius of curvature in the main scanning direction, rz denotes a radius of curvature in the auxiliary scanning direction (which is omitted for a rotationally symmetrical surface), d denotes a distance between adjacent surfaces on the optical axis, and n denotes a refractive index at a wavelength of 780 nm.

TABLE IV

fa=200.0 mm scan width: 320 mm design λ: 780 nm

No.	ry	rz	d	n
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
#3	inf.	--	67.00	

#4	568.65	-23.70	7.40	1.48617
#5	7235.14	--	4.00	
#6	inf.	--	21.50	1.51072
#7	-123.77	-19.40	195.65	

Surface #4 is a progressive toric aspherical surface, surface #5 is a surface on which the diffraction lens structure is formed, surface #6 is a planar surface, and surface #7 is a Z toric surface. Conical coefficients and aspherical coefficients for surface #4 are indicated in TABLE V, and the numerical structure of the diffraction lens structure on surface #5 is indicated in TABLE VI.

TABLE V

fd at the design wavelength: 5677.4 mm

Macroscopic shape

r	7235.14
κ	0.0
A4	-1.670×10^{-6}
A6	2.655×10^{-10}
A8	-1.900×10^{-14}
A10	0.0

Coefficients for additional path length $\Delta\phi(h)$

P2	-1.1291×10^{-1}
P4	6.0796×10^{-7}
P6	-3.0940×10^{-9}
P8	2.3439×10^{-13}
P10	-7.7883×10^{-17}
D	8.17×10^{-6}

Fig. 5 is a graph showing the lateral chromatic aberration of the scanning optical system according to the second embodiment.

THIRD EMBODIMENT

Fig. 6 is a plan view of the scanning optical system 3000, showing an arrangement of optical elements, according to a third embodiment of the invention. The scanning optical system 3000 include an fθ lens 130b, which includes a first lens 135, a second lens 136, and a diffraction lens structure 135a formed on a surface of the first lens 135. The first lens 135 is a plastic lens, and the second lens 136 is a glass lens. In TABLE VII, a numerical structure of the optical elements, on the photoconductive drum side thereof with respect to the cylindrical lens is indicated. In TABLE VII, fa denotes a focal length of the fθ lens 130b in the main scanning direction, ry denotes a radius of

curvature in the main scanning direction, rz denotes a radius of curvature in the auxiliary scanning direction (which is omitted for a rotationally symmetrical surface), d denotes a distance between adjacent surfaces on the optical axis, and n denotes a refractive index at wavelength of 780 nm.

TABLE VII

fa=199.7 mm   scan width: 320 mm   design λ: 780 nm

No.	ry	rz	d	n
#1	inf.	-50.0	4.00	1.51072
#2	inf.	--	94.50	
#3	inf.	--	68.00	
#4	-207.48	--	8.70	1.48617
#5	-264.05	-56.42	3.00	
#6	inf.	--	20.00	1.76591
#7	-149.04	-51.23	202.73	

Surface #4 is a surface on which the diffraction lens structure is formed, surface #5 is a progressive toric aspherical surface, surface #6 is a planar surface, and surface #7 is a Z toric surface. The numerical structure of

the diffraction lens structure on surface #4 is indicated in TABLE VIII, and the conical coefficients and aspherical coefficients for surface #5 are indicated in TABLE IX.

TABLE VIII

fd at design wavelength: 3700.3 mm

Macroscopic shape

r	-207.48
κ	0.0
A4	-1.472×10^{-6}
A6	6.166×10^{-10}
A8	-7.251×10^{-14}
A10	0.0

Coefficients for additional path length $\Delta\phi(h)$

P2	-1.7324×10^{-1}
P4	-1.1333×10^{-4}
P6	3.8473×10^{-8}
P8	-9.3384×10^{-12}
P10	1.1066×10^{-15}
D	2.59×10^{-5}

TABLE IX

Conical and aspherical coefficients for surface #5

κ	0.0		
A4	-8.901×10^{-7}	B1	2.157×10^{-5}
A6	3.352×10^{-10}	B2	2.310×10^{-6}
A8	-3.235×10^{-14}	B3	0.0
A10	0.0	B4	5.929×10^{-10}

Fig. 7 is a graph showing the lateral chromatic aberration of the scanning optical system according to the third embodiment.

TABLE X indicates values fa/fd and fa/fg of each embodiment.

TABLE X

condition	1st emb.	2nd emb.	3rd emb.
$0.0 < fa/fd < 0.20$	0.06	0.04	0.05
$0.75 < fa/fg < 1.20$	0.99	0.83	1.03

As is known from TABLE X, in each embodiment, conditions (1) and (2) are satisfied. Therefore, in each embodiment, the lateral chromatic aberration and variation

of power due to a change of refractive index can be suppressed. Therefore, with a printer employing the scanning optical system according to the present invention, color drift of printed images due to variations of wavelengths of the laser beams for respective color components, and due to uneven distribution of temperature inside the printer can be suppressed, and color images can be printed accurately.

The present disclosure relates to the subject matter contained in Japanese Patent Application No. HEI 11-248465, filed on September 2, 1999, which is expressly incorporated herein by reference in its entirety.

What is claimed is:

1. A tandem type printer, comprising:

a plurality of scanning optical systems, each of which includes a laser source that emits a laser beam, and a deflector that deflects the laser beam to scan, in a main scanning direction, within a predetermined angular range, said plurality of scanning optical system respectively including a plurality of fθ lenses that converge the laser beams emitted by said plurality of scanning optical systems; and

a plurality of photoconductive drums arranged to receive the laser beams emitted from said plurality of fθ lenses, respectively, the laser beams scanning on said plurality of photoconductive drums, respectively, images formed on said plurality of photoconductive drums being developed and transferred in an overlaid fashion on a sheet,

wherein each of said plurality of fθ lenses includes:

a glass lens that provides substantially all the power, in the main scanning direction, of said each of said plurality of fθ lenses;

a plastic lens that compensates for aberrations; and

a diffraction lens structure that compensates for a lateral chromatic aberration in the main scanning direction, and

wherein each $f\theta$ lens satisfies conditions:

$0.0 < fa/fd < 0.20$; and

$0.75 < fa/fg < 1.20$,

where, fa represents a focal length of the $f\theta$ lens in the main scanning direction;

fd represents a focal length of said diffraction lens structure in the main scanning direction; and

fg represents a focal length of said glass lens in the main scanning direction.

2. The tandem type printer according to claim 1, wherein said diffraction lens structure is formed on a refraction surface of said plastic lens in each $f\theta$ lens.

3. An $f\theta$ lenses for a laser beam printer, comprising:

a glass lens that provides substantially all the power, in a main scanning direction, of said $f\theta$ lens;

a plastic lens that compensates for aberrations; and

a diffraction lens structure that compensates for a lateral chromatic aberration in the main scanning direction,

wherein each $f\theta$ lens satisfies conditions:

$0.0 < fa/fd < 0.20$; and

$0.75 < fa/fg < 1.20$,

where, fa represents a focal length of the $f\theta$ lens in the main scanning direction;

fd represents a focal length of said diffraction lens structure in the main scanning direction; and

fg represents a focal length of said glass lens in the main scanning direction.

4. The fθ lens according to claim 3, wherein said diffraction lens structure is formed on a refraction surface of said plastic lens.

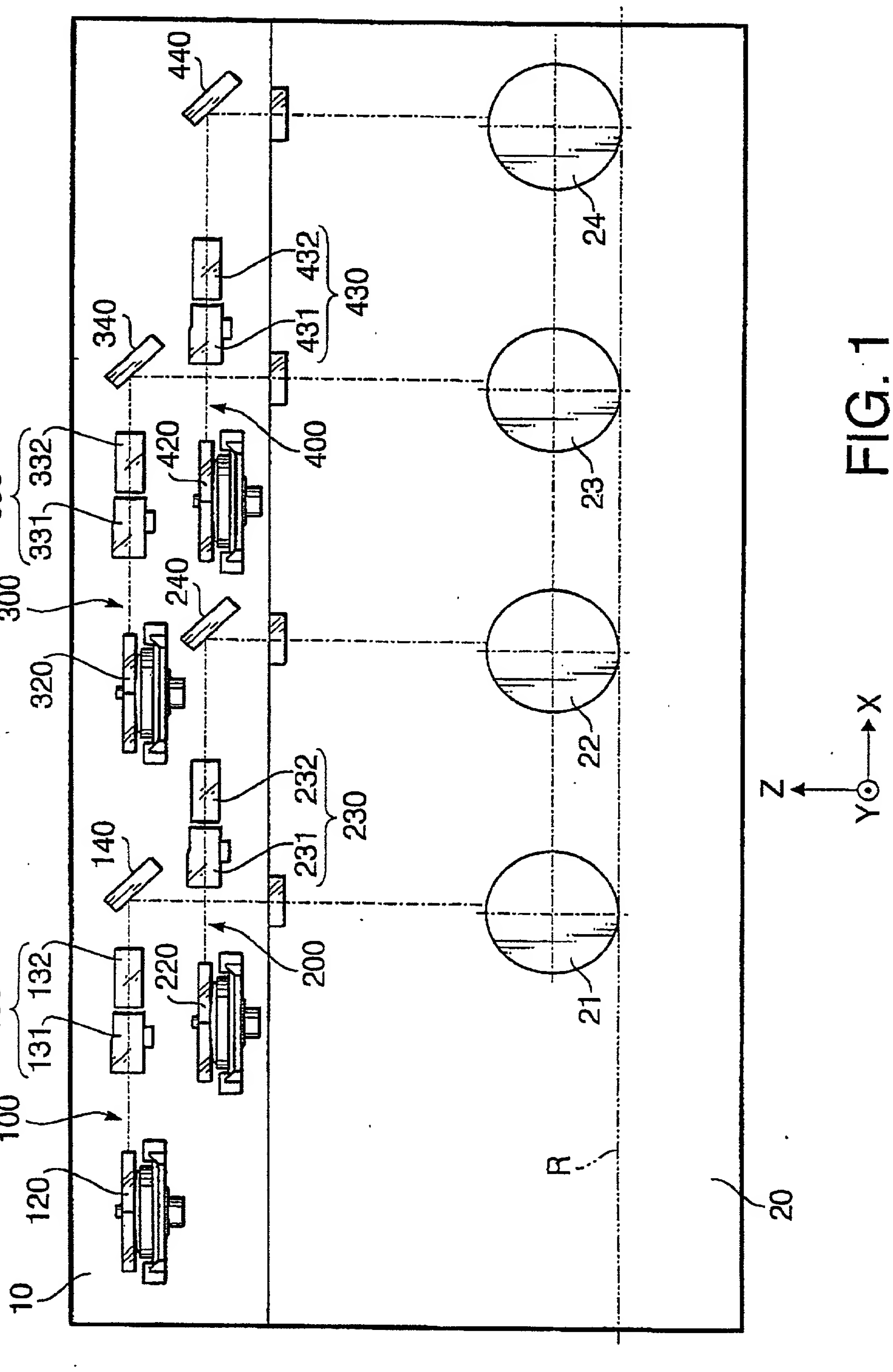
Abstract of the Disclosure

A tandem type printer is provided with a plurality of scanning optical systems, a plurality of fθ lenses and photoconductive drums, which correspond to the scanning optical systems, respectively. Each scanning optical system includes a laser source and a deflector that deflects the laser beam emitted by the laser source to scan, in a main scanning direction, within a predetermined angular range. The deflected laser beam is converged by the fθ lens on the corresponding photoconductive drum and form an image. Images formed on the plurality of photoconductive drums are developed and transferred on a sheet in an overlaid fashion. Each fθ lens includes a glass lens that is burdened with substantially all the power, in the main scanning direction, of the fθ lens, and a plastic lens that is burdened with compensation for aberrations of the fθ lens. Further, a diffraction lens structure is formed to compensate for a lateral chromatic aberration of the fθ lens in the main scanning direction. Each fθ lens satisfies conditions:

$0.0 < fa/fd < 0.20$; and

$0.75 < fa/fg < 1.20$,

where, fa, fd and fg represent focal lengths of the fθ lens, diffraction lens structure, and glass lens, in the main scanning direction, respectively.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131
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140
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231
232
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300
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330
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420
430
431
432
440
20
21
22
23
24
R
Z
X
Y

FIG. 1

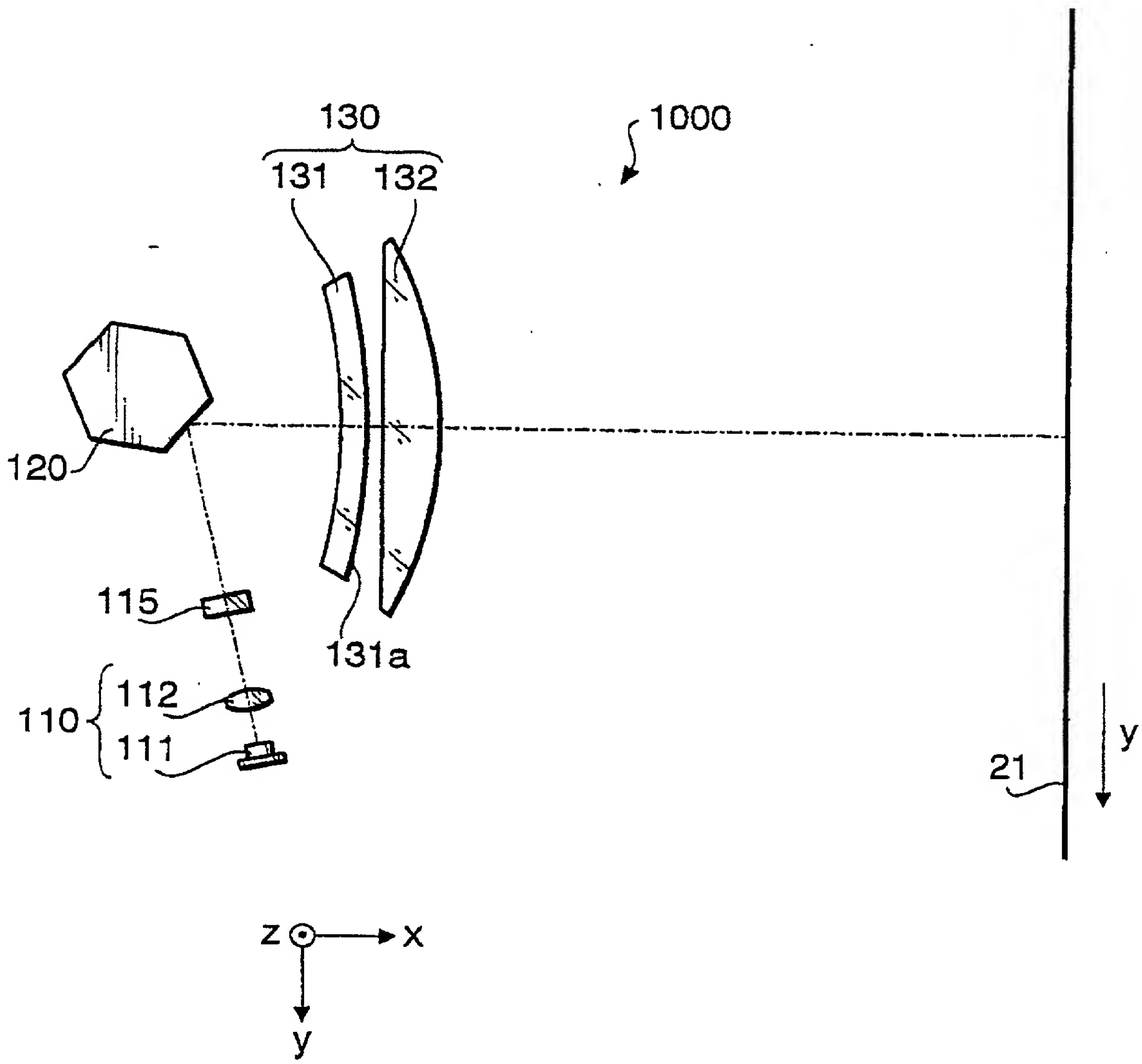

FIG. 2

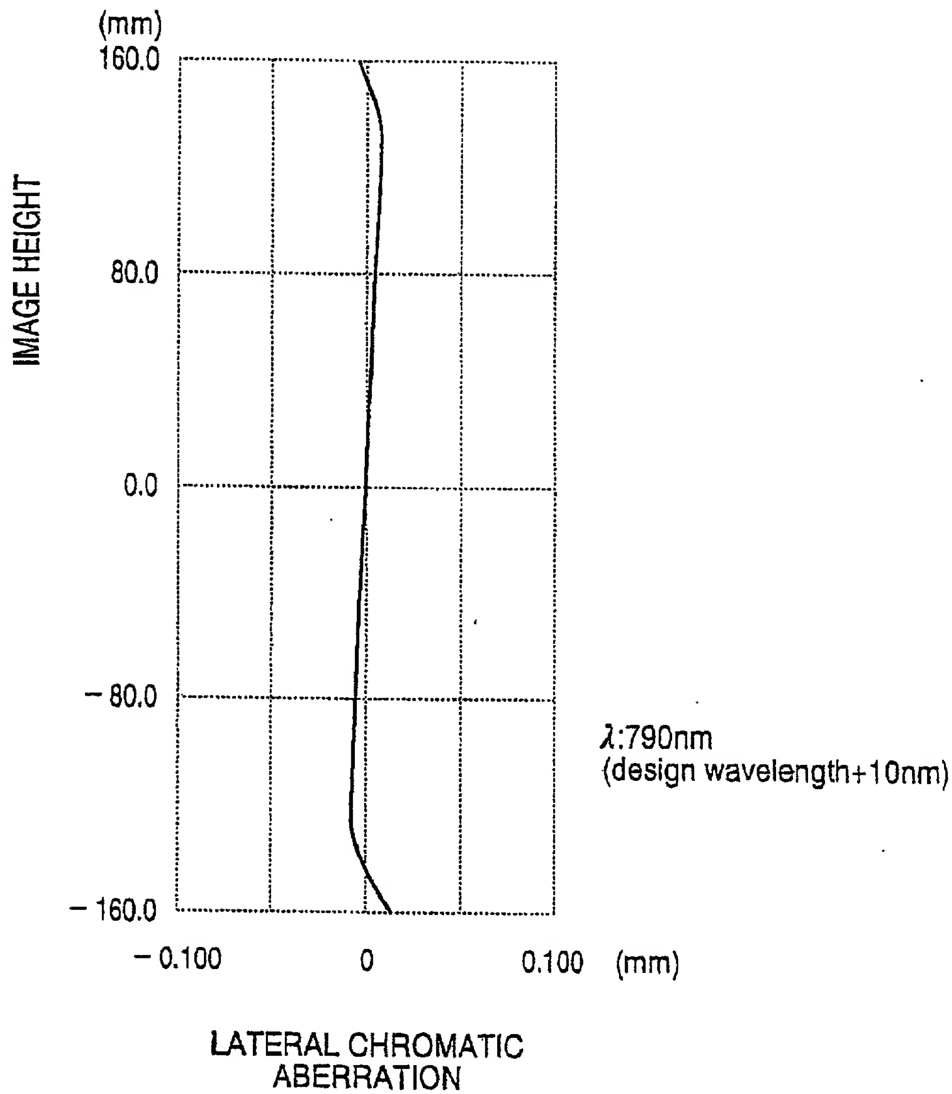
(mm)
160.0
IMAGE HEIGHT
80.0
0.0
−80.0
−160.0
−0.100
0
0.100
(mm)
λ:790nm
(design wavelength+10nm)
LATERAL CHROMATIC
ABERRATION

FIG. 3

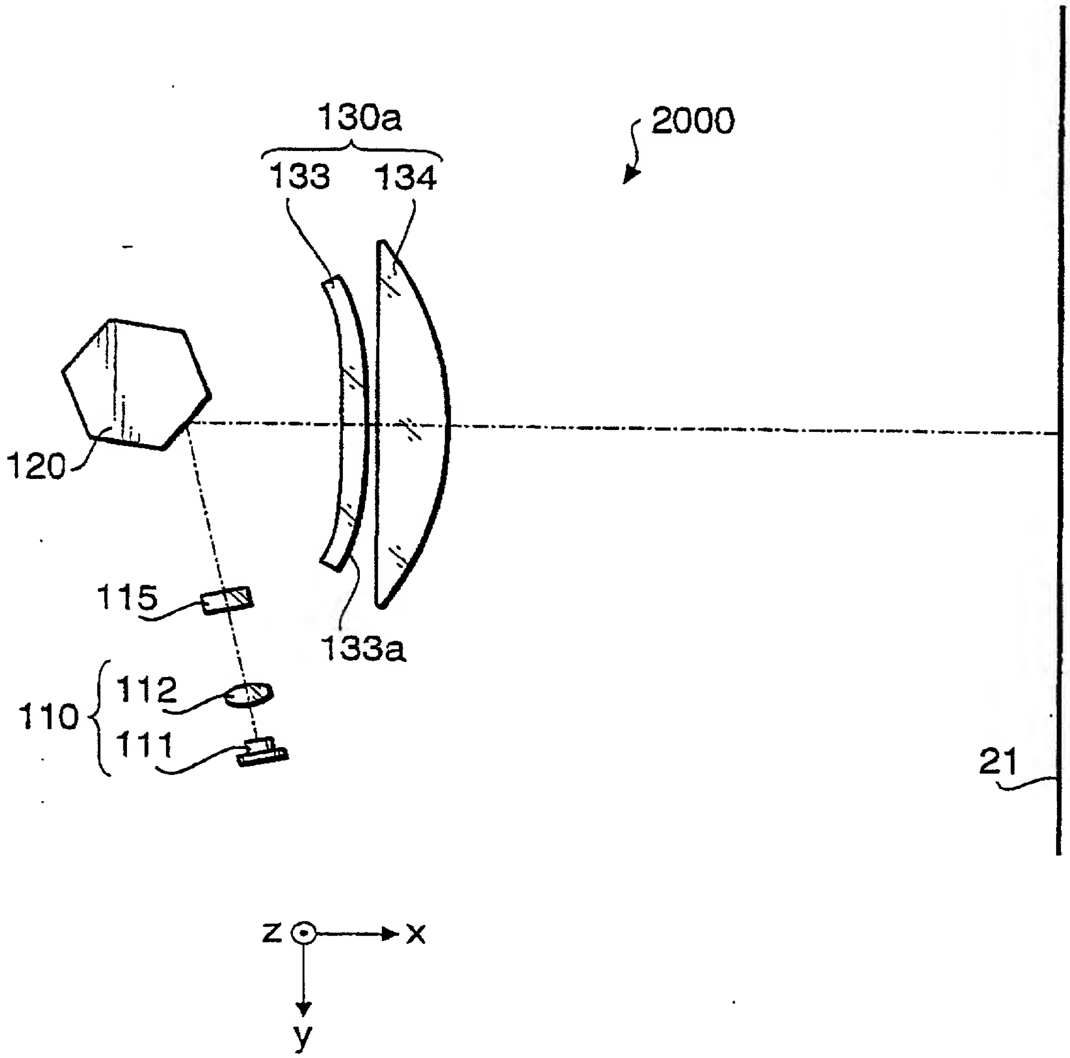

FIG. 4

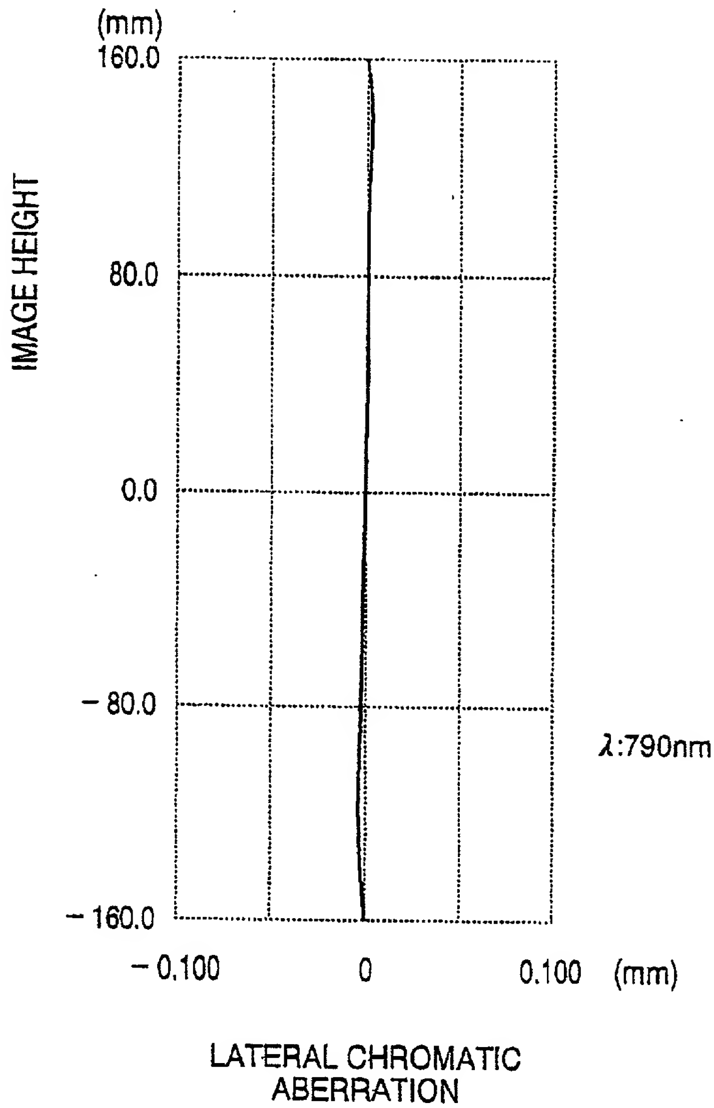
(mm)
160.0
80.0
0.0
− 80.0
− 160.0
IMAGE HEIGHT
− 0.100
0
0.100
(mm)
λ:790nm
LATERAL CHROMATIC
ABERRATION

FIG. 5

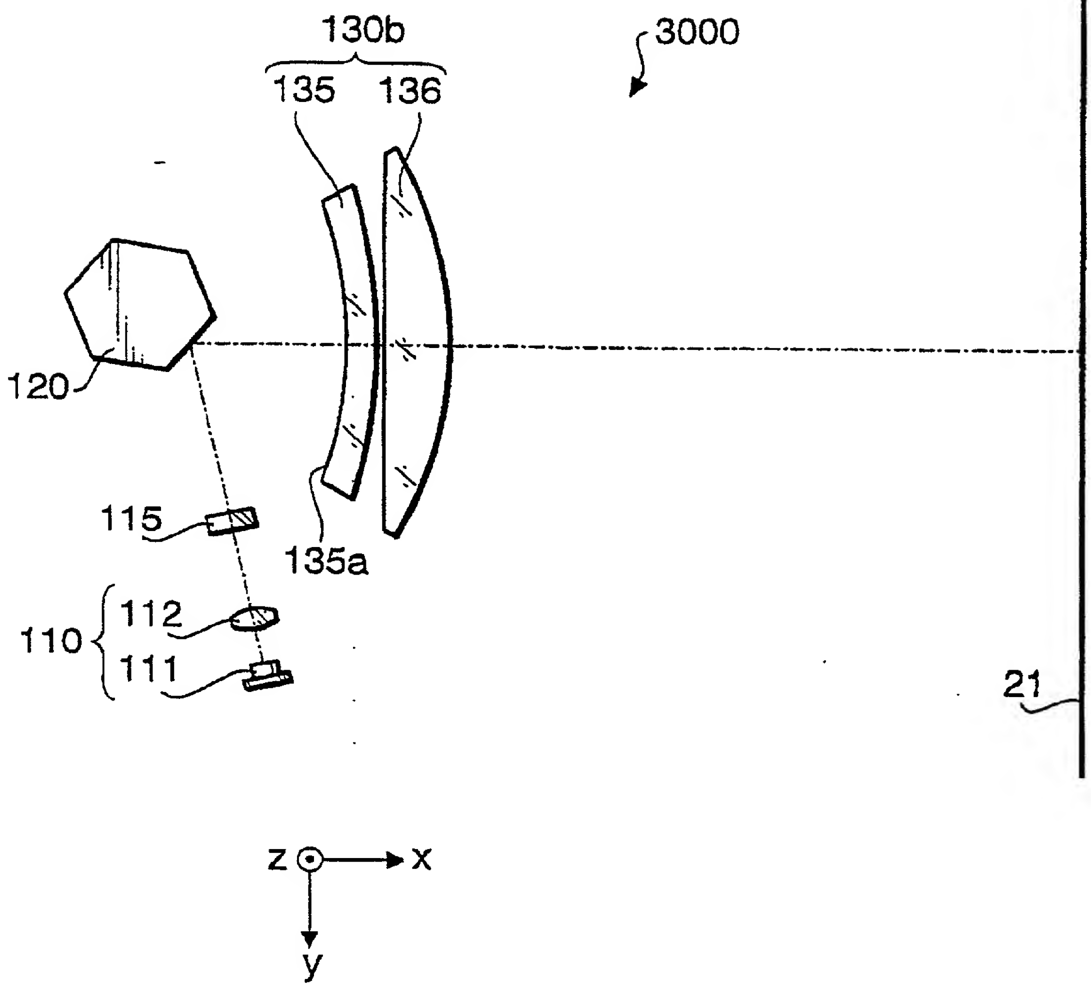

FIG. 6

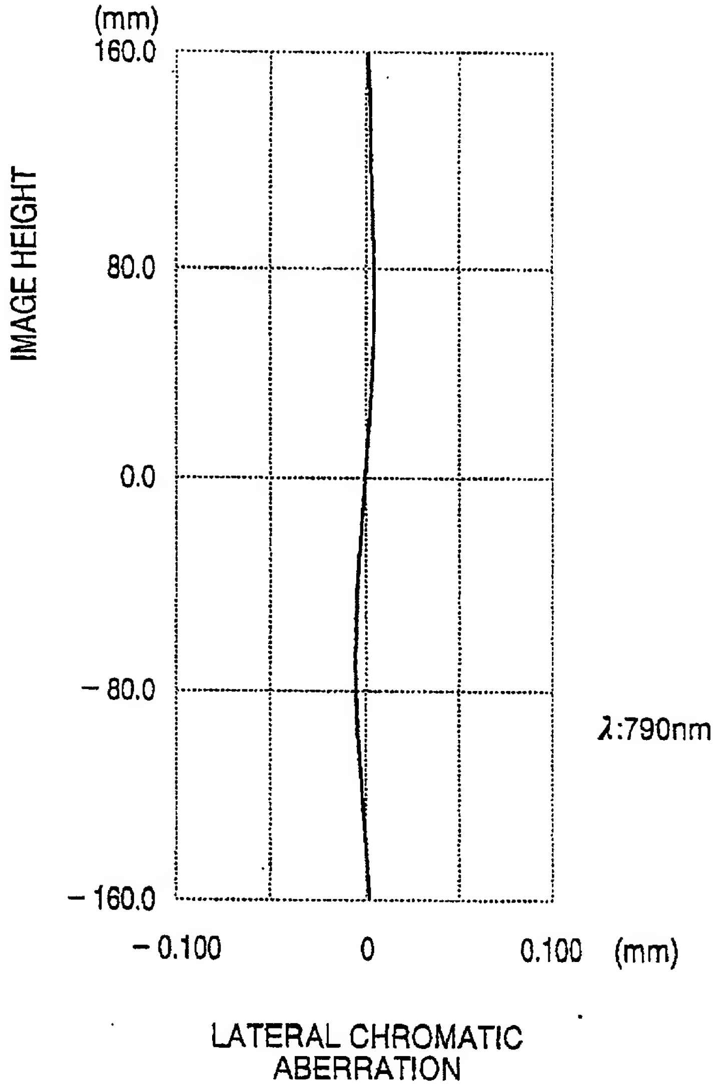
(mm)
160.0
80.0
0.0
− 80.0
− 160.0
IMAGE HEIGHT
− 0.100
0
0.100
(mm)
λ:790nm
LATERAL CHROMATIC
ABERRATION

FIG. 7

Declaration and Power of Attorney For Utility or Design Patent Application
特許出願宣言書

Japanese Language Declaration

私は、下欄に氏名を記載した発明者として、以下のとおり宣言する：

私の住所、郵便の宛先および国籍は、下欄に氏名に続いて記載したとおりであり、

名称の発明に関し、請求の範囲に記載した特許を求める主題の本来の、最初にして唯一の発明者である(一人の氏名のみが下欄に記載されている場合)か、もしくは本来の、最初にして共同の発明者である(複数の氏名が下欄に記載されている場合)と信じ、

上記発明の明細書(下記の欄でX印がついていない場合は、本書に添付)は、

☐ ____年____月____日に提出され、

米国出願番号 ____________ とし、

(該当する場合) ____年____月____日に訂正されました。又は、

特許協定条約国際出願番号 ____________ とし、

(該当する場合) ____年____月____日に訂正されました。

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私は合衆国法典第35部第119条(a−d)項又は第365条(b)項に基づく、下記の外国特許出願又は発明者証出願、或いは第365条(a)項に基づく、少なくても米国以外の1ケ国を指名したPCT国際出願の外国優先権を主張し、更に優先権の主張に係わる基礎出願の出願日前の出願日を有する外国特許出願、又は発明者証出願或るいはPCT国際出願を以下に“なし”の箱に印をつけることにより明記する：

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

SCANNING OPTICAL SYSTEM FOR TANDEM TYPE PRINTER

the specification of which is attached hereto unless the following box is checked:

☐ was filed on ____________ as

United States Application Number ____________

and was amended on ____________ (if applicable) or,

PCT International Application Number ____________

and was amended on ____________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority under Title 35, United States Code §119(a-d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designated at least one country other than the United States, listed below. I have also identified below, by checking the "No" box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed:

Prior foreign applications 先の外国出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願の年月日)	Priority claimed 優先権の主張 Yes あり	No なし
HEI 11-248465	Japan	2/September/1999	☒	☐
			☐	☐

☐ その他の外国特許出願番号は別紙の追補優先権欄にて記載する。

☐ Additional foreign application numbers are listed on a supplemental priority sheet attached hereto.

Letter Version

Japanese Language Utility or Design Patent Application Declaration

私は、合衆国法典第35部第119条(e)項に基づく、下記の合衆国仮特許出願の利益を主張する。

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Day/Month/Year Filed) 出願の年月日
(Application No.) (出願番号)	(Day/Month/Year Filed) 出願の年月日
(Application No.) (出願番号)	(Day/Month/Year Filed) 出願の年月日

☐ その他の合衆国仮特許出願番号は別紙の追補優先権欄にて記載する。

☐ Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.

私は、合衆国法典第35部第120条に基づく下記の合衆国特許出願、又は第365条(c)項に基づく合衆国を指名したPCT国際出願の利益を主張し、本願の請求の範囲各項に記載の主題が合衆国法典第35部第112条第1項規定の態様で、先の合衆国特許出願又はPCT国際出願に開示されていない限度において、先の出願の出願日と本願の国内出願日又はPCT国際出願日の間に有効となった連邦規則法典第37部第1章第56条に記載の特許要件に所要の情報を開示すべき義務を有することを認める。

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s), or §365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

(Application No.) (出願番号)	(Day/Month/Year Filed) (出願の年月日)	(現況) (特許済み、係属中 放棄済み)	(Status) (patented, pending, abandoned)
(Application No.) (出願番号)	(Day/Month/Year Filed) (出願の年月日)	(現況) (特許済み、係属中 放棄済み)	(Status) (patented, pending, abandoned)

☐ その他の合衆国又は国際特許出願番号は別紙の追補優先権欄にて記載する。

☐ Additional U.S. or international application numbers are listed on a supplemental priority sheet attached hereto.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

私、下記署名者は、ここに記載の米国弁護士または代理人に本出願に関し特許商標庁にて取られるいかなる行為に関して、同米国弁護士又は代理人が、私に直接連絡なしに私の外国弁護士或るいは法人代表者からの指示を受け取り、それに従うようここに委任する。この指示を出す者が変更の場合には、ここに記載の米国弁護士又は代理人にその旨通知される。

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Case # P19585

Japanese Language Utility or Design Patent Application Declaration

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顧客番号 7055

現在選任された弁護士は下記の通りである。

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorney(s) and/or agent(s) associated with the Customer Number provided below to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to that Customer Number:

CUSTOMER NUMBER 7055

The appointed attorneys presently include:

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Bruce H. Bernstein	Reg. No. 29,027	William E. Lyddane	Reg. No. 41,568
James L. Rowland	Reg. No. 32,674	William Pieprz	Reg. No. 33,630
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同第２共同発明者の署名 日付	Second Inventor's signature Date
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（第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。）

(Supply similar information and signature for third and subsequent joint inventors.)